design allows the solution to be determined entirely though analytical techniques. In addition, a planar via-less microwave crossover using this technique was proposed. The experimental results show that the proposed crossover at 5 GHz has a minimum isolation of 32 dB. It also has low in-band insertion loss and return loss of 1.2 dB and 18 dB, respectively, over more than 44 percent of bandwidth at room temperature.

This microstrip-CPW transition requires the microstrip line to be split into two sections. Each section is connected to a microstrip quarter-wavelength open-ended stub. A slotline is also placed perpendicular to the microstrip section. The slot is connected to a grounded-end quarter-wavelength slotline and generates a microstrip-slotline transition. When two of these sections are placed in parallel and with the microstrip section combined at transition, a microstrip-CPW transition is formed. The slotline radiation is suppressed as two slots are excited with the electric field in an opposite direction, which cancels the radiation in far field. The invention on the crossover consists of the invented microstrip-CPW transitions combined back-to-back and a microstrip low-pass filter. One signal is crossed through to the microstrip layer, while the other signal is crossed through the CPW line located on the ground plane of the microstrip line. The microstrip low-pass filter produces a narrow line at the crossing point to enhance the system isolation. It also produces broadband response in the operating frequency band.

The microstrip-CPW transition allows a microwave signal to travel from microstrip line to CPW line with low radiation loss. The crossover allows two microwave signals to cross with minimal parasitic coupling.

*This work was done by Thomas Stevenson, Kongpop U-Yen, Edward Wollack, Samuel Moseley, and Wen-Ting Hsieh of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).GSC-15705-1*

# Wheel-Based Ice Sensors for Road Vehicles

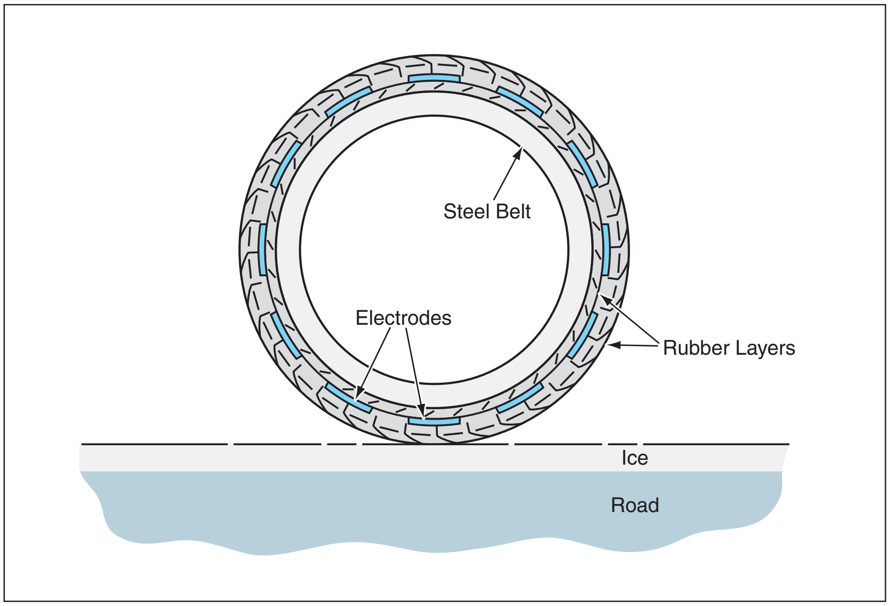
## Ice would be sensed via its electric permittivity.

*Lyndon B. Johnson Space Center, Houston, Texas*

Wheel-based sensors for detection of ice on roads and approximate measurement of the thickness of the ice are under development. These sensors could be used to alert drivers to hazardous local icing conditions in real time. In addition, local ice-thickness measurements by these sensors could serve as guidance for the minimum amount of sand and salt required to be dispensed locally onto road surfaces to ensure safety, thereby helping road crews to utilize their total supplies of sand and salt more efficiently.

Like some aircraft wing-surface ice sensors described in a number of previous *NASA Tech Briefs* articles, the wheel-based ice sensors are based, variously, on measurements of changes in capacitance and/or in radio-frequency impedance as affected by ice on surfaces. In the case of ice on road surfaces, the measurable changes in capacitance and/or impedance are attributable to differences among the electric permittivities of air, ice, water, concrete, and soil. In addition, a related phenomenon that can be useful for distinguishing between ice and water is a specific transition in the permittivity of ice at a temperature-dependent frequency. This feature also provides a continuous calibration of the sensor to allow for changing road conditions.

Several configurations of wheel-based ice sensors are under consideration. For example, in a simple two-electrode capacitor configuration, one of the electrodes would be a circumferential electrode within a tire, and the ground would be used as the second electrode. Optionally, the steel belts that are already standard parts of many tires could be used as the circumferential electrodes. In another example (see figure), multiple electrodes would be embedded in rubber between the steel belt and the outer tire surface. These electrodes would be excited in alternating polarities at one or more suitable audio or radio frequencies to provide nearly continuous monitoring of the road surface under the tire. In still another example, one or more microwave stripline(s) or coplanar waveguide(s) would be embedded in a tire near its outer surface; in comparison with lower-frequency capacitive devices, a device of this type could be more sensitive.




**Multiple Electrodes Embedded in a Tire** near its outer surface would be excited with alternating voltages. The capacitance between the electrodes at the bottom would be measured as an indication of the thickness of ice (if any) on the road.

*This work was done by G. Dickey Arndt, Patrick W. Fink, and Phong H. Ngo of Johnson Space Center and James R. Carl (independent consultant). Further information is contained in a TSP (see page 1). MSC-23565-1*